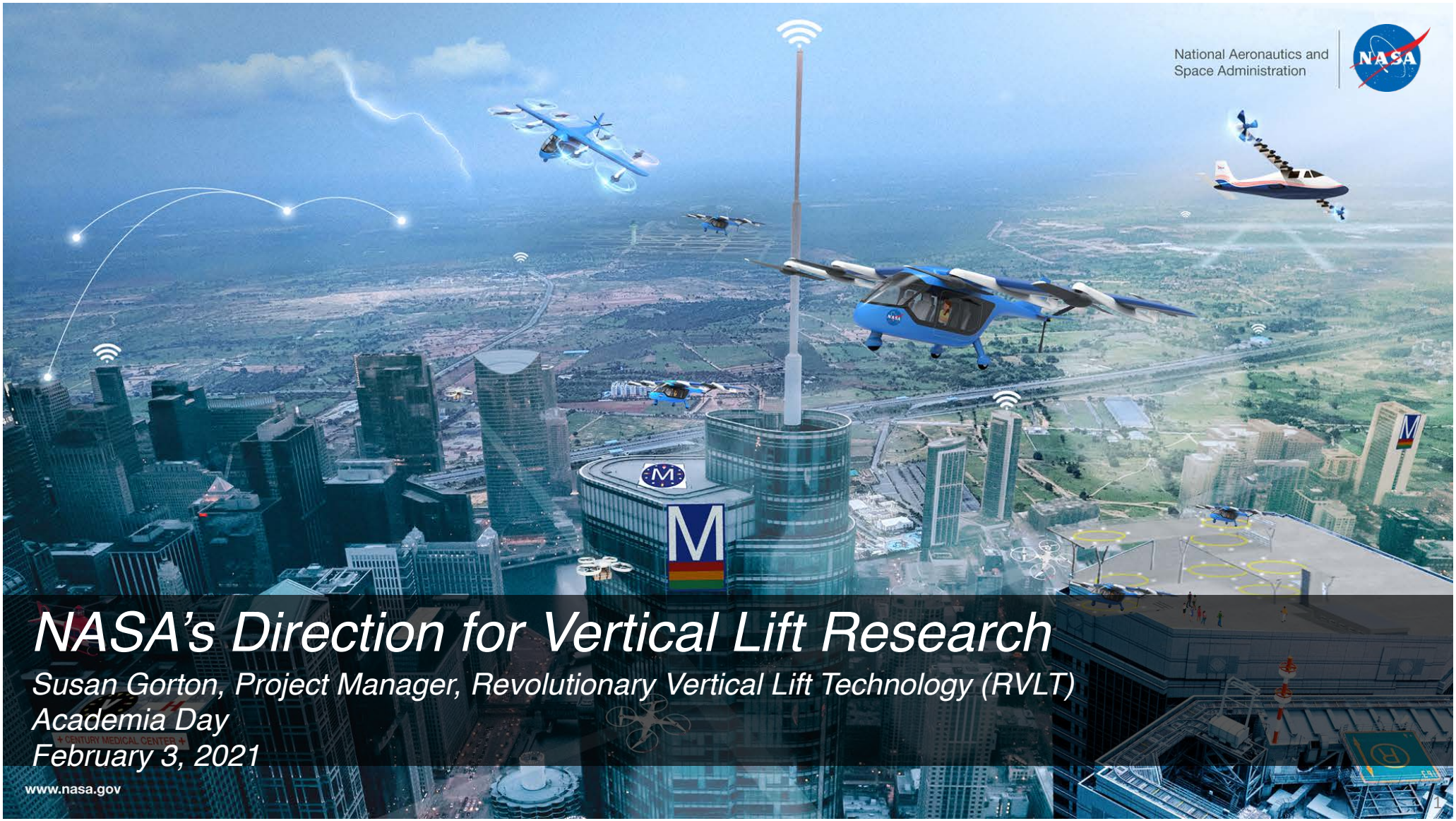



# NASA's Direction for Vertical Lift Research

*Susan Gorton, Project Manager, Revolutionary Vertical Lift Technology (RVLT)*

*Academia Day*

*February 3, 2021*

# NASA Aeronautics Six Strategic Thrusts and Community Visions




**Safe, Efficient Growth in Global Operations**
- Achieve safe, scalable, routine, high-tempo airspace access for all users

**Innovation in Commercial Supersonic Aircraft**
- Achieve practical, affordable commercial supersonic air transport

**Ultra-Efficient Subsonic Transports**
- Realize revolutionary improvements in economics and environmental performance for subsonic transports with opportunities to transition to alternative propulsion and energy

**Safe, Quiet, and Affordable Vertical Lift Air Vehicles**
- Realize extensive use of vertical lift vehicles for transportation and services including new missions and markets

**In-Time System-Wide Safety Assurance**
- Predict, detect and mitigate emerging safety risks throughout aviation systems and operations

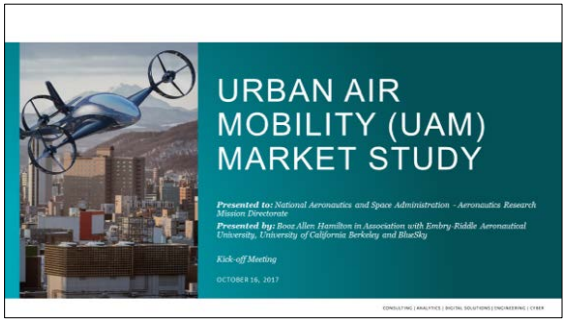
**Assured Autonomy for Aviation Transformation**
- Safely implement autonomy in aviation applications

Strategic Implementation Plan (released 2020) at: https://www.nasa.gov/aeroresearch/strategy
National Academies Study (2020) at: https://www.nap.edu/catalog/25646/advancing-aerial-mobility-a-national-blueprint

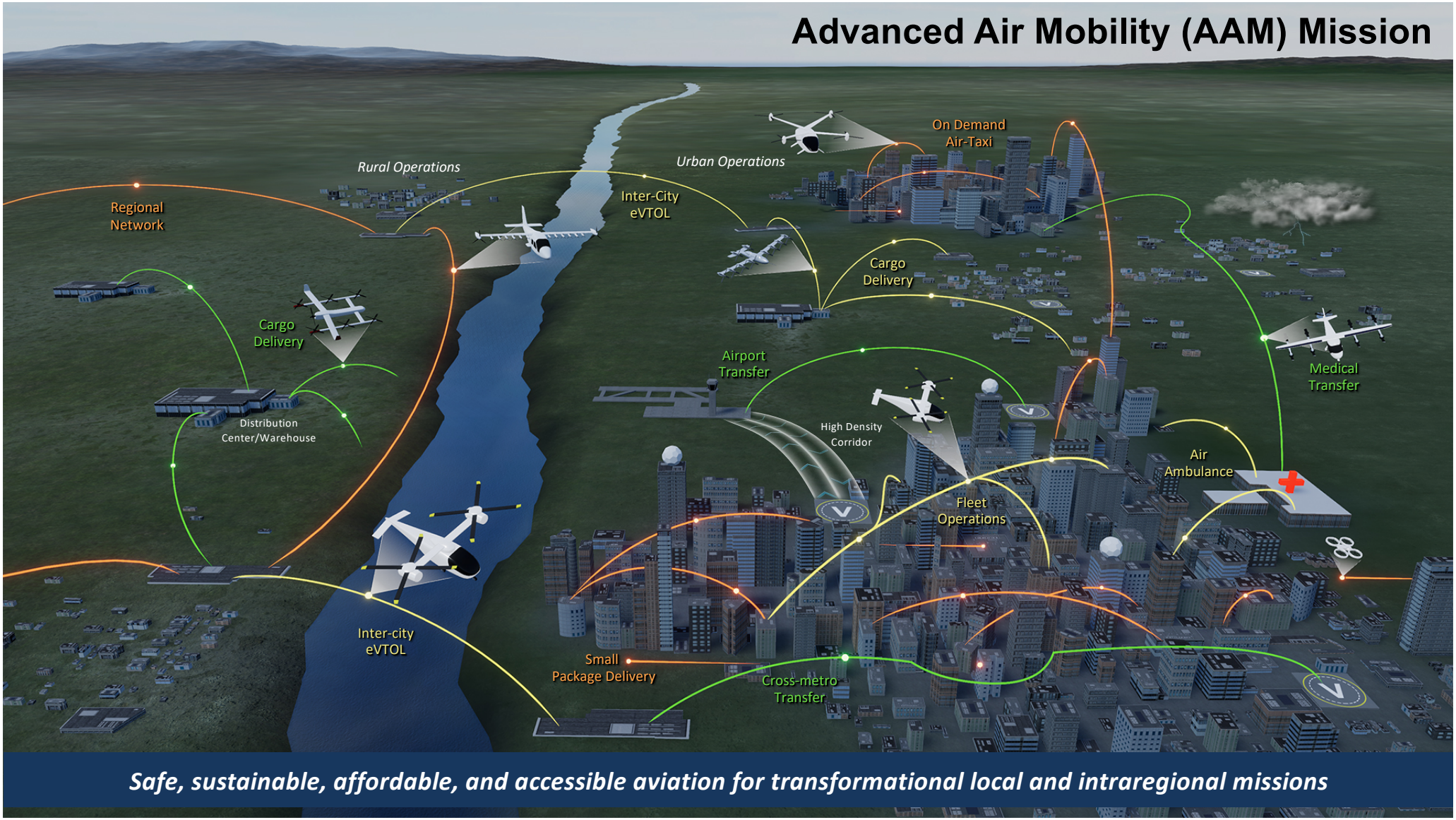
# AAM and UAM

NASA Focus is on Advanced Air Mobility (AAM) Missions

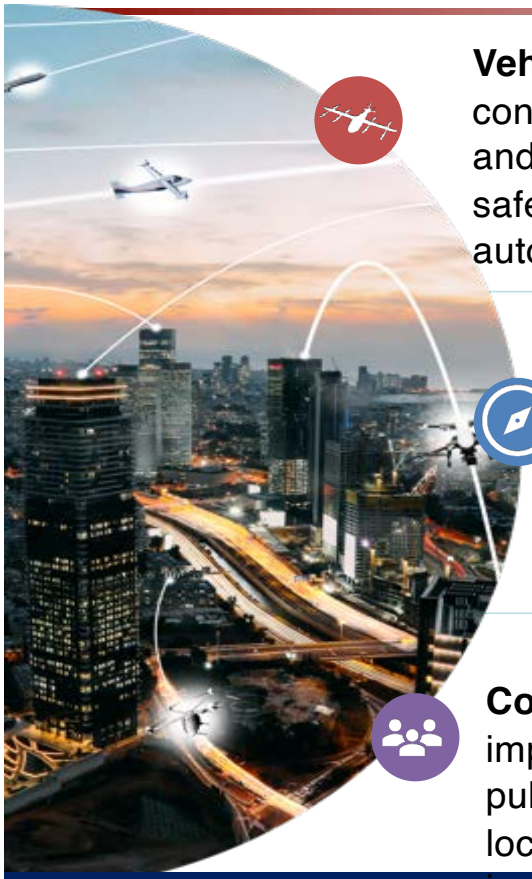
- AAM missions characterized by
  < 300 nm range
- Vehicles require increased automation and are likely electric or hybrid-electric
- Rural and urban operations and cargo delivery are included
- Urban Air Mobility (UAM) is a subset of AAM and is the segment that is projected to have the most economic benefit and be the most difficult to develop
  - UAM requires an advanced urban-capable vehicle
  - UAM requires an airspace system to handle high-density operations


https://www.nasa.gov/aam-studies-reports/


Advanced Air Mobility (AAM) Mission
Rural Operations
Urban Operations
Regional Network
Inter-City eVTOL
On Demand Air-Taxi
Cargo Delivery
Cargo Delivery
Airport Transfer
Medical Transfer
Distribution Center/Warehouse
High Density Corridor
Air Ambulance
Fleet Operations
Inter-city eVTOL
Small Package Delivery
Cross-metro Transfer
Safe, sustainable, affordable, and accessible aviation for transformational local and intraregional missions

# AAM Mission Critical Commitment – What NASA will Deliver



**Vehicle Development and Operations** Develop concepts and technologies to define requirements and standards addressing key challenges such as safety, affordability, passenger acceptability, noise, automation, etc.

**Airspace Design and Operations** Develop UTM-inspired concepts and technologies to define requirements and standards addressing key challenges such as safety, access, scalability, efficiency, predictability, etc.

**Community Integration** Create robust implementation strategies that provide significant public benefits and catalyze public acceptance, local regulation, infrastructure development, insurance and legal frameworks, etc.

**Critical Commitment:**

**Based on validated operational concepts, simulations, analyses, and results from National Campaign demonstrations, the AAM Mission will deliver aircraft, airspace, and infrastructure system and architecture requirements to enable sustainable and scalable medium density advanced air mobility operations**

**Achieving a "validated system architecture" will require *enabling activities* such as 1) the AAM National Campaign Series 2) a robust Ecosystem Partnership model and 3) NASA ARMD Portfolio Execution.**

# AAM Mission Critical Commitment

**Vehicle Development and Operations** Develop

**RVLT contribution: Deliver enabling vehicle technologies**

automation, etc.

**Airspace Design and Operations** Develop UTM-inspired concepts and technologies to

**Contribution from NASA Airspace projects**

access, scalability, efficiency, predictability, etc.

**Community Integration** Create robust implementation strategies that provide significant

**https://nari.arc.nasa.gov/aamecosystem**

local regulation, infrastructure development, insurance and le

**Critical Commitment:**

**Based on validated operational concepts, simulations, analyses, and results from National Campaign demonstrations, the AAM Mission will deliver aircraft, airspace, and infrastructure system and architecture requirements to enable sustainable and scalable medium density advanced air mobility operations**

**Achieving a "validated system architecture"**
**2) a robust Ecosystem P**

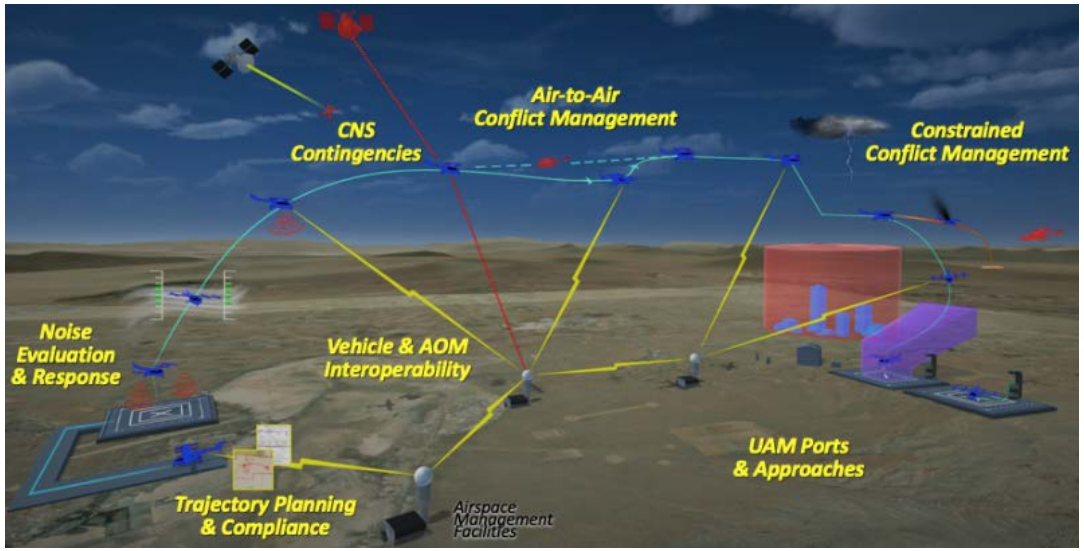
**https://www.nasa.gov/aamnationalcampaign**

# National Campaign Series Fundamentals

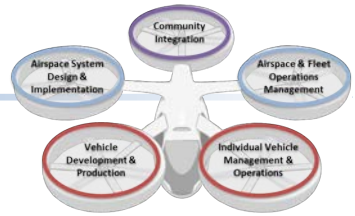
- Series Emphasis on Operational Scenarios, and remaining flexible to industry needs
  - NC-DT assesses the readiness of external ranges and partners to collect comprehensive data in support of NC-1 (~spring 2021)
  - NC-1 scenarios will move participants closer to operations by baselining operational expectations and identifying gaps in AAM (~summer 2022)
  - NC-2-4, and associated developmental testing, will progressively mature advanced UAM vehicle configurations and automation research

- Primary test ranges determined by the locations where partners plan to fly

- Ecosystem WG's will be the primary means for the entire community to provide inputs into the Series

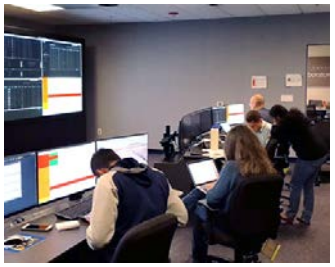


# NASA AAM Facilities and Capabilities

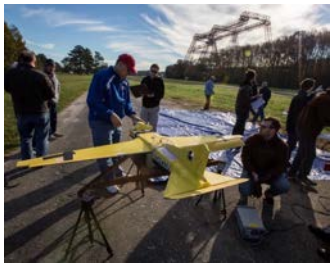




Air Traffic Operations Lab

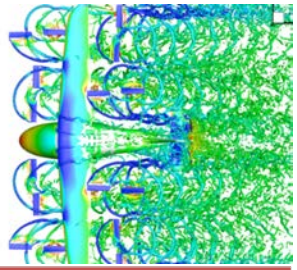

Airspace Operations Lab


Ames UAM Lab

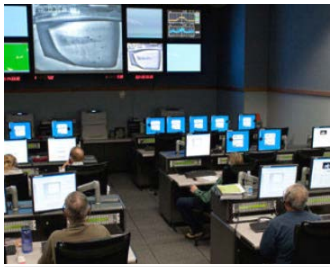

CERTAIN Range

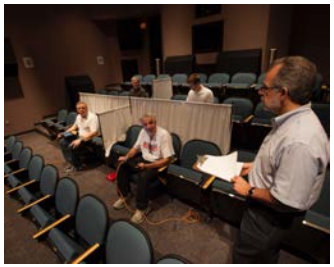

Cockpit Motion Facility


Cognitive Engineering Lab


Computational Fluid Dynamics


Developmental UAM Simulator - Flyer

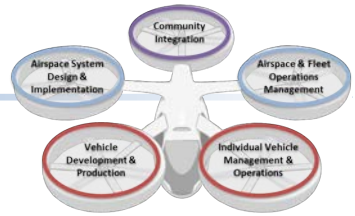

Dryden Aeronautical Test Range


Exterior Effects Room


Flight Loads Lab


Future Flight Central

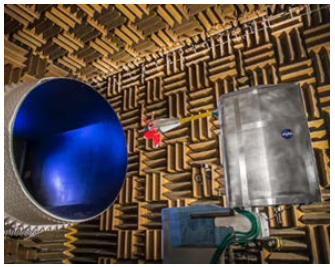
# NASA AAM Facilities and Capabilities Cont.





Icing Research


Landing and Impact Research Facility


Low Speed Aeroacoustic Wind Tunnel

Mobile Acoustics Facility


Mobile Operations Facility


Research Flight Deck

Testbed Virtual Infrastructure


UAS Flight Test Control Room


Vertical Motion Simulator


X-57 Maxwell


12’ Tunnel–Low-cost Exploratory Facility


14- by 22-Foot Subsonic Tunnel

Many others including wind tunnels, aircraft, ranges, cockpit sims, supercomputers, etc.

# NASA RVLT Project Research Areas

**Ames Research Center**

- Aeromechanics
- System Analysis
- Computational Methods
- Experimental Capability
- Flt Dyn & Ctrl
- Acoustics

**Armstrong Flight Research Center**

- National Campaign execution
- UAM electric system and flt control integration
- eVTOL reliability

**Glenn Research Center**

- Hybrid/ Electric Systems
- Electro-Mech Powertrains
- Small Turboshaft Engines
- Icing
- System Analysis
- Impact Dynamics
- Acoustics

**Langley Research Center**

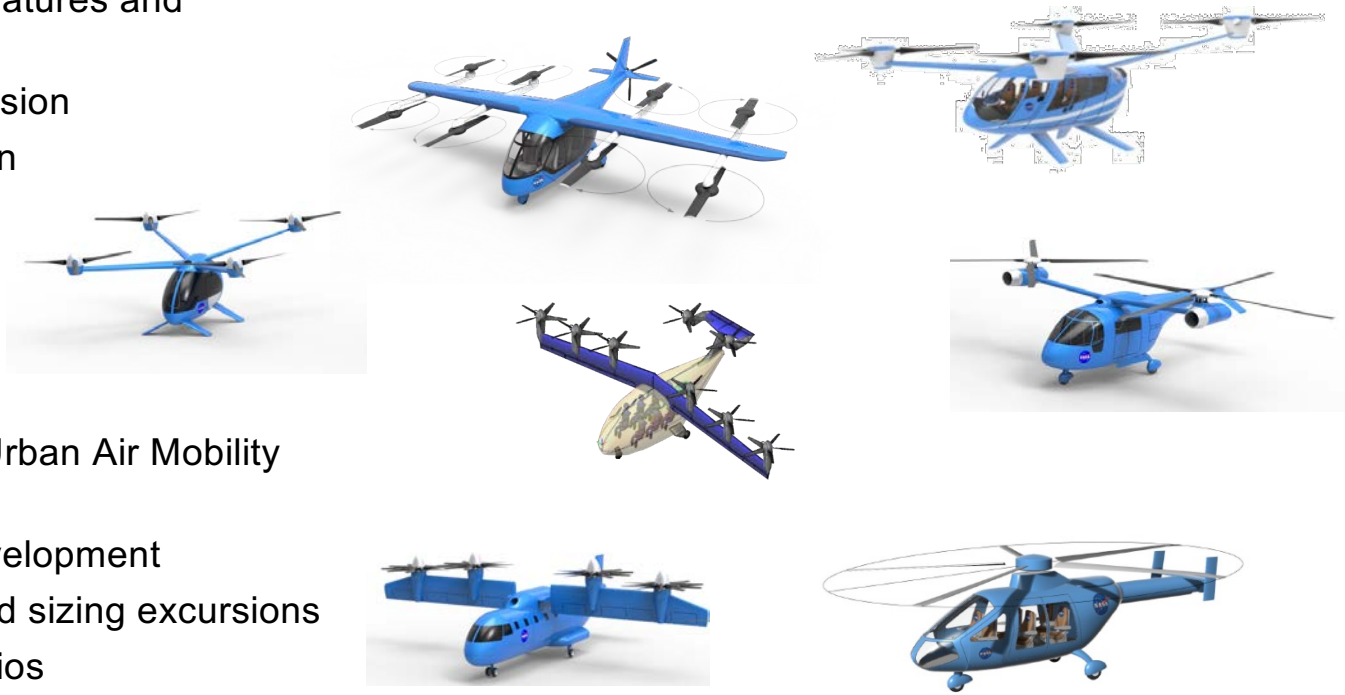
- Acoustics
- Computational Methods
- Aeromechanics
- Experimental Capability
- Impact Dynamics
- System Analysis




# NASA Concept Vehicles – Generic Geometries that Capture Many UAM Features

NASA reference vehicles ◆ Widely shared ◆ Fully documented ◆ Realistic performance ◆ Realistic set of compromises ◆ No plans to build or fly these concepts ◆

- Vehicles contain relevant UAM features and technologies
  - Battery, hybrid, diesel propulsion
  - Distributed electric propulsion
  - High efficiency rotors
  - Quieter rotors
  - Wake interactions
- Provide configurations for
  - Communication of NASA's Urban Air Mobility research
  - Design and analysis tool development
  - Technology trade studies and sizing excursions
  - Modeling operational scenarios
  - Common configurations for studies in acoustics, flight dynamics, propulsion reliability, etc.



# Research Areas for UAM eVTOL Vehicles


## PROPULSION EFFICIENCY
high power, lightweight battery
light, efficient, high-speed electric motors
power electronics and thermal management
light, efficient diesel engine
light, efficient small turboshaft engine
efficient powertrains

## PERFORMANCE
aircraft optimization
rotor shape optimization
hub and support drag minimization
airframe drag minimization

## ROTOR-ROTOR INTERACTIONS
performance, vibration, handling qualities
aircraft arrangement
vibration and load alleviation

## NOISE AND ANNOYANCE
low tip speed
rotor shape optimization
flight operations for low noise
aircraft arrangement/ interactions
cumulative noise impacts from fleet ops
active noise control
cabin noise
electric motor noise
metrics and requirements

## SAFETY and AIRWORTHINESS
FMECA (failure mode, effects, and criticality analysis)
component reliability and life cycle
crashworthiness
Electric motor reliability assessment
propulsion system failures
high voltage operational safety
high voltage protection devices

**Quadrotor + Electric**

**Tiltwing + TurboElectric**

**Side-by-side + Hybrid**

**Lift+Cruise + TurboElectric**

## OPERATIONAL EFFECTIVENESS
disturbance rejection (control bandwidth, control design)
Ops in moderate to severe weather
passenger acceptance/ ride quality
cost (purchase, maintenance, DOC)

## ROTOR-WING INTERACTIONS
conversion/transition
interactional aerodynamics
flow control

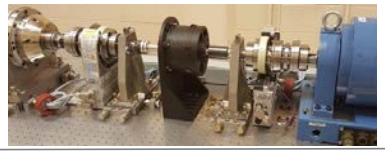
## AIRCRAFT DESIGN
weight, vibration
handling qualities
active control

## STRUCTURE AND AEROELASTICITY
structurally efficient wing and rotor support
rotor/airframe stability
crashworthiness
durability and damage tolerance
high-cycle fatigue

**Red = primary RVLT research area**
**Blue = secondary RVLT research area**

# RVLT Near Term Focus for Research
## FY20-FY22

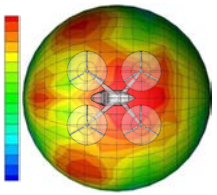
**Vehicle Propulsion Reliability**



**Reliable and Efficient Propulsion Components for UAM**

- Re-configure laboratories for electric propulsion testing
- Conduct initial single string tests
- Develop tools to assess motor reliability
- Develop high reliability conceptual motor design

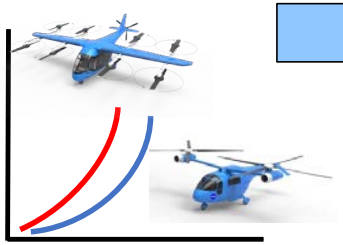
**UAM Fleet Noise**



**UAM Operational Fleet Noise Assessment**

- Generate Noise Power Distance (NPD) database for several UAM reference configurations and trajectories
- Conduct Fleet Noise assessments
- Initiate psychoacoustic testing to assess human response to UAM vehicles

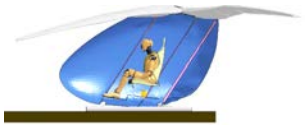
**Noise and Performance**



**Tools to Explore the Noise and Performance of Multi-Rotor UAM Vehicles**

- Plan and conduct validation experiments
- Improve efficiency and accuracy of conceptual design tools
- Conduct high-fidelity configuration CFD for validation and reference
- Improve community transition and training for analysis tools

**Safety and Acceptability**



**Targeted Research in These Areas**

- Occupant protection and survivability
- Acceptable handling and ride qualities for UAM vehicles
- Ice accretion and shedding for UAM

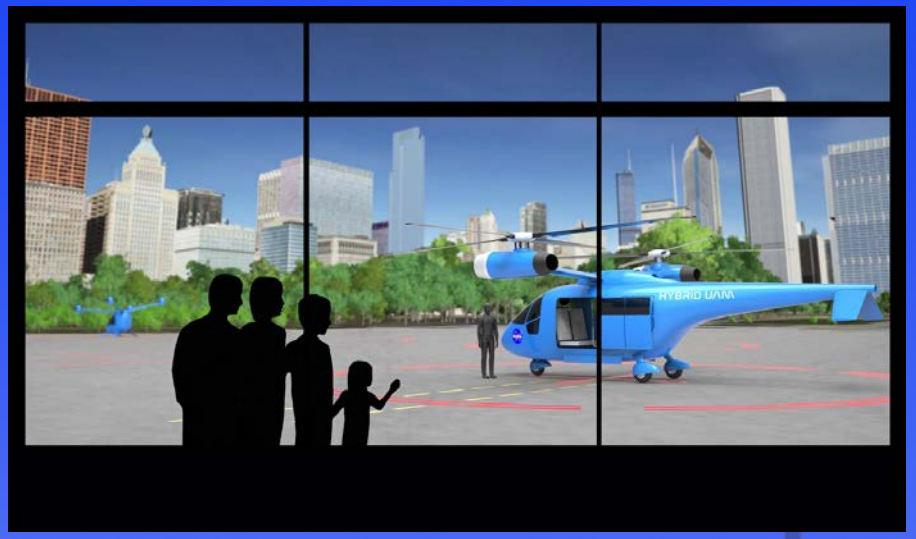
# Summary

NASA is focused on

- Advanced Air Mobility as one of the priorities for Aeronautics research
- Vertical lift vehicle technology supporting Urban Air Mobility
- Airspace technologies for AAM
- National Campaign Demonstrations
- Ecosystem Working Groups

RVLT is focused on

- VTOL R&T to improve noise and safety



*The RVLT vision is to create a future where VTOL configurations operate quietly, safely, efficiently, affordably and routinely as an integral part of everyday life.*